

DOCUMENT RESUME

ED 259 955

SE 045 947

AUTHOR Cothron, Julia H.; Thompson, Ertle
TITLE Research on the Development of Ecological Concepts and Conceptual Systems: Implications for the Elementary Educator.
PUB DATE Apr 85
NOTE 34p.; Paper presented at the Annual Meeting of the National Science Teachers Association (33rd, Cincinnati, OH, April 18-20, 1985).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Academic Ability; *Concept Formation; *Ecology; *Elementary School Science; Instructional Program Divisions; Intermediate Grades; Performance Factors; *Science Course Improvement Projects; Science Education; *Science Instruction; Sex Differences
IDENTIFIERS *Science Curriculum Improvement Study; Science Education Research

ABSTRACT

Student variables which influence attainment of ecological concepts and conceptual systems were investigated. Researcher-designed paper/pencil and free-sort categorization tests were administered to 256 Science Curriculum Improvement Study (SCIS) students in grades 4-6. Findings are: (1) grade and ability, not sex, influenced concept attainment and conceptual system; (2) sequence of concept development was not influenced by grade, ability, or sex; (3) sixth-grade students conceptualized life requirements, feeding relationships, food-mineral cycle, and community-environment interactions but not the higher-order classificatory concepts or oxygen-carbon dioxide cycle; (4) discipline experts, not elementary students, possessed conceptual systems based upon higher-order concepts; and (5) concept attainment was promoted by a conceptual system similar to the discipline structure. Recommendations include continuing concrete activities, investigating effectiveness of SCIS and other elementary programs in developing higher-order classificatory concepts and the oxygen-carbon dioxide cycle, emphasizing development of conceptual systems, and investigating teachers' ability to effectively utilize concrete experiences and concept maps. (Author/JN)

* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *

ED259955

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

☒ This document has been reproduced as
received from the person or organization
originating it.

☐ Minor changes have been made to improve
reproduction quality.

• Points of view or opinions stated in this docu-
ment do not necessarily represent official NIE
position or policy.

Research on the Development of Ecological

Concepts and Conceptual Systems:

Implications for the Elementary

Educator

Julia H. Cothron

Hanover County Schools, Ashland, Virginia

Ertle Thompson

University of Virginia

A Paper Presented at the National Science Teachers Convention

Cincinnati, Ohio, April 18-20, 1985.

"PERMISSION TO REPRODUCE THIS
MATERIAL HAS BEEN GRANTED BY

Julia H. Cothron

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)."

SE 045947

Biographical Resumes

Julia H. Cothron

Director of Secondary Education and Science

Hanover County Schools

200 Berkley Street

Ashland, VA 23005

B.S. Valdosta State College

MEd Valdosta State College

Edd University of Virginia

Ertle Thompson

Professor of Science Education

University of Virginia

Curry Memorial School of Education - Ruffner Hall

Charlottesville, VA 22903

AB University of Kentucky

MEd University of Virginia

Edd University of Virginia

Abstract

Student variables which influence attainment of ecological concepts and conceptual systems were investigated. The researcher designed Ecosystem Test (paper/pencil) and Ecology Card Sort (free-sort categorization) were administered to 256 SCIS students, grades 4-6. Statistics included three-way ANOVA, latent partition analysis, and multiple regression. Findings were: (a) grade and ability, not sex, influenced concept attainment and conceptual system; (b) sequence of concept development was not influenced by grade, ability or sex; (c) sixth graders conceptualized life requirements, feeding relationships, food-mineral cycle, and community-environment interactions but not the higher-order classificatory concepts or oxygen-carbon dioxide cycle; (d) discipline experts, not elementary students, possessed conceptual systems based upon higher-order concepts; (e) concept attainment was promoted by a conceptual system similar to the discipline structure. Recommendations were: (a) continue concrete activities; (b) investigate effectiveness of SCIS and other elementary programs in developing higher-order classificatory concepts and oxygen-carbon dioxide cycle; (c) emphasize development of conceptual systems; (d) investigate teachers' ability to effectively utilize concrete experiences and concept maps.

Introduction

Because of concern for the deteriorating quality of the environment, a trend emerged in the early seventies to incorporate ecological concepts into the elementary curriculum. The Science Curriculum Improvement Study, SCIS, was a leader in the development of elementary environmental curricula (Karplus et al., 1974). Major ecological concepts included in the program were: (a) the classificatory concepts: producer, consumer, decomposer, environmental factors, community, ecosystem, and (b) the relational concepts: food-mineral cycle and oxygen-carbon dioxide cycle. Instruction was based upon a three-part learning cycle: Exploration (concrete experiences), Invention (concept development), and Discovery (concept application). Through group concept-mapping activities, the curriculum emphasized development of a conceptual system of the ecosystem similar to the discipline structure. The author conducted a research study to investigate the effect of student variables on the attainment of ecological concepts and conceptual systems. The purpose of this paper is to summarize the research findings and to discuss implications for the design of elementary curricula and the training of elementary teachers.

Summary of the Research Study

Methodology

A stratified sample of 288 subjects was randomly selected from five of the fourteen elementary schools in a southwestern

Virginia county which had used the SCIS Program for seven years. The sample was stratified by grade level (4, 5, 6), sex (M, F), and ability. Based on the second grade score on the Otis-Lennon Mental Ability Test (1969) was used to categorize students as below average ($\bar{x} = 80.6$), average ($\bar{x} = 100.1$), or above average ($\bar{x} = 120.2$) ability.

Two researcher designed instruments which had been developed in a prior pilot study were utilized. The paper-and-pencil Ecosystem Test (Cronbach's Alpha = .826) assessed mastery of the concepts: producer, consumer, decomposer, environmental factors, community, ecosystem, food-mineral cycle, and oxygen-carbon dioxide cycle. The 46 items required students to select examples, definitions, critical attributes, and principles (Voelker, 1972). The Ecology Card Sort (Pearson's test/retest = .347, $p < .001$) assessed the student's conceptual system through free-sort categorization of fifteen concepts.

The discipline structure for the Ecology Card Sort was obtained by administering the sort to eight biologists, ecologists, and science educators and statistically averaging the results with latent partition analysis (Harasyn & Precht, 1971). The discipline structure contained five groups:

1. producer - bush, corn oak;
2. consumer - beetle, grasshopper, prairie dog;
3. decomposer - bacteria, mold;

4. environmental factors - carbon dioxide, water;
5. community.

The discipline experts had similar sort patterns (cohesiveness = .960) and exhibited little disagreement (ambiguity = .07) about the placement of concepts into groups.

The research instruments were administered during the regularly scheduled 70 minute science period by the classroom teacher. The students' descriptive data and responses were coded for key punching and subsequent processing by the University of Virginia's Cyber 172 computer.

The major statistics utilized were three-way ANOVA, Scheffe Multiple Range Test, Spearman Rank Order Correlation, multiple regression, and latent partition analysis (Harason & Precht; Nie, Hull, Jenkins, Steinbrenner & Bent, 1975). Custom-made computer program were used to obtain the SIC value, similarity of student sort and discipline structure, and to prepare data for entry into the latent partition analysis program (Bishop, 1982a, 1982b, 1982c). The statistics utilized with each major research question are outlined in Table 1.

Findings, Interpretation, and Discussion

The research findings related to a) the influence of grade level, ability level, and sex on conceptual understanding of the ecosystem, the sequence of concept development, and the type of conceptual system; and b) the influence of the conceptual system

on ecological concept attainment are summarized in Table 1.

Insert Table 1 about here

Conceptual understanding of ecosystem. Grade and ability level, but not sex, significantly influenced the development of ecological concepts. The mean scores of fourth (22.58), fifth (24.92), and sixth (28.75) grade students differed significantly ($F = 33.9$, $p \leq .001$). A significant difference was also found among the mean scores of students with below average (22.32), average (24.26), and above average (28.66) ability ($F = 33.41$, $p \leq .001$). The mean achievement scores of male (25.49) and female (25.34) students were not significantly different ($F = .138$, $p \leq .711$). There were no significant first or second order interactions.

The significant influence of grade level and ability level was expected and is supported by the findings of Boulanger (1981), Clark (1971), and Voelker (1973) that age and ability are positively related to concept development. The non-significant finding for sex is supported by the research of Perry and Merkle (1976) with first graders studying the SCIS Organisms unit, the research of Tamppari (1970) with fifth and seventh graders studying photosynthesis and respiration, and a major synthesis of concept development studies by Clark. The finding conflicts

with research by Allen (1975) with elementary students, grades 2-8, studying feeding relationships and with various studies with secondary students in which male students scored higher on ecological concepts (Buhl, 1977; Perkes, 1973; Richmond & Morgan, 1977). Perhaps the concrete experiences in the exploration stage of the SCIS Learning Cycle reduced any differential backgrounds of male and female students.

Sequence of development of ecological concepts. The sequence or ordering of Ecosystem Test items from least to most difficult was equivalent for fourth, fifth, and sixth grade students; students with below average, average, and above average ability; and male and female students. Descriptive information from the Ecosystem Test (See Table 2) revealed that the following concepts were understood by 60% or more of the students in the designated grade level(s):

1. feeding relationships depicted in food webs (grades 4, 5, 6);
2. life requirements of plants and animals (grades 4, 5, 6);
3. rotting of dead plants and animals to minerals (grades 5, 6);
4. interactions of plants (producers), animals (consumers), and decay organisms via the food-mineral cycle (grades 5, 6);
5. examples of major components of the ecosystem (grade

6):

6. grouping of organisms into communities which interacted with the environment (grade 6).

Approximately 50% of the sixth grade students answered questions involving the interaction of organisms via the oxygen-carbon dioxide cycle. Less than 50% of the sixth grade students answered items involving definitions or critical attributes of the higher-order classificatory concepts. The response patterns for ability and grade level were similar. No difference in response patterns existed for male and female students. The response patterns could not be explained in terms of reading difficulty alone.

Insert Table 2 about here

The non-significant impact of grade level, ability level, or sex on the sequence of concept development was expected and is consistent with the literature. The sequence for ecological concepts was similar to the sequence in SCIS and other elementary science programs. Mastery of life requirements of plants and animals and feeding relationships by fourth graders is congruent with the research of Allen and Perry and Merkle and supports placement of these concepts in the lower elementary curriculum. The ability of fifth and sixth graders to conceptualize the interaction of plants, animals, and decay organisms via the

food-mineral cycle and the interaction of organisms with the environment supports placement of these concepts in the upper elementary curriculum. Achievement levels of less than 50% on the oxygen-carbon dioxide cycle by sixth graders suggest that the concept is too abstract and that the SCIS Ecosystem unit should be re-evaluated. The ability of sixth graders to select examples and principles but not to define or articulate the critical attributes of the higher-order classificatory concepts: producer, consumer, decomposer, and environmental factors was consistent with Voelker's (1972) sequence but unexpected given the emphasis in the fifth and sixth grade SCIS units. Serious questions are raised concerning the appropriateness of the concepts and/or ability of teachers to utilize the SCIS Learning Cycle. The concepts may be inherently too difficult for Voelker (1973) reported that elementary students do not understand abstract relationships involving gases and chemical/physical changes and Lowell (1979) hypothesized that elementary learners would have difficulty with abstract relational or higher-order classificatory concepts. Butts (1963) found that concrete experiences were insufficient to develop conceptual understanding; teachers must direct students' attention to the relationships involved. Based upon the findings of Clark and Tennyson and Park (1980), concept development would be retarded if teachers did not focus students' attention on the critical/noncritical attributes,

provide students with a concept definition that identified and articulated the critical attributes, and encourage students to verbalize concepts and extend the concepts beyond the examples provided in the SCIS program. Additional investigations on the appropriateness of the concepts and the ability of teachers to effectively utilize concrete experiences as the basis for concept development are needed.

Similarity of a student's conceptual system to the discipline structure. Grade and ability level, not sex, significantly influenced the similarity of a student's conceptual system to the discipline structure as revealed by the SIC value. The mean SIC value of sixth grade students (.595) was significantly higher than the mean SIC value of fourth graders (.512). The SIC values of students with above average ability (.588) and below average ability (.525) also differed significantly. Mean SIC values for male (.547) and female (.566) students were not significantly different ($F=2.70$, $p<.102$). There were no significant first or second order interactions. Descriptive information on sort patterns of fourth, fifth, and sixth grade students is given in Table 3.

Three identical groups were found in the student sort patterns: (a) bush, oak; (b) beetle, grasshopper, prairie dog; (c) bacteria, mold. Variations existed in the placement of the remaining concepts into two or three groups. The grouping

pattern of sixth grade students, which most closely resembled the discipline structure, contained two additional groups: (a) corn, water; and (b) carbon dioxide, community, consumer, decomposer, environmental factors, producer. In general, older or more intelligent students sorted the same concepts together with greater frequency (high cohesiveness value), but exhibited less agreement concerning the placement of concepts into groups (high ambiguity value).

Insert Table 3 about here

The finding that grade and ability level, but not sex, influenced the type of conceptual system was expected and substantiated by grouping studies conducted by Goldman and Levine (1963) and Reichard, Schneider, and Rapaport (1944). The use of class name, such as producer, by discipline experts but not elementary students is congruent with Preece's (1978) finding that unsophisticated learners have conceptual systems which are based upon small isolated groups of relational concepts while those of sophisticated learners are based upon tightly organized hierarchies similar to the discipline structure. The card data supported the paper-pencil test data, for ability to identify critical attributes is a precursor to using the concepts as a subsumer. Students did place plants, animals, foods, and decayers together, suggesting that some

classification system was utilized. Goldman and Levine found that grouping of concepts by non-essential features, function, or material composition preceded grouping by abstract features or class name. Lowell found that formal thought, which is not typical of elementary students, is necessary for hierarchical classification. Possible explanations for the inability of sixth grade students to duplicate the discipline structure despite considerable emphasis in the fifth and sixth grade units are: (a) teachers were unaware of the importance of the activities and did not engage in sufficient discussion of the reasons for placement of organisms into a given category, (b) the task was inherently too difficult when structure (e.g., the pyramid) was not provided, or (c) the students were not provided with sufficient examples outside the SCIS program to allow them to generalize the concept(s).

Influence of conceptual system on attainment of ecological concepts. The SIC value for a male student ($R = .5670$, $p \leq .001$) and a female student ($R = .686$, $p \leq .0001$) was a significant predictor of the score on the Ecosystem Test when the influence of grade level and ability level were removed. The variance explained by the SIC value was very small for both male (4.3%) and female (4.4%) students.

The significant influence of a conceptual system similar to the discipline structure on concept attainment supports the findings of Hambleton and Sheehan (1977) and Wiinn (1980)

and the emphasis placed upon structure in the SCIS Program.

Implications for Elementary Science

Based upon the research findings, and informal conversations with SCIS teachers during the pilot and research studies, the following recommendations are made:

Evaluate the Effectiveness of Elementary Programs in Developing Ecological Concepts

The SCIS materials which developed life requirements, feeding relationships, and the food-mineral cycle were effective and should be retained. Use of similar materials in other elementary science programs should be encouraged. However, the SCIS materials which developed the higher-order classificatory concepts and the oxygen-carbon dioxide cycle should undergo additional testing to determine if the limited concept development was a function of the population or typical of all students completing the SCIS program. Additional studies should also be conducted to determine the success of other elementary science programs in developing the higher-order classificatory concepts and the oxygen-carbon dioxide cycle.

Sensitize Elementary Teachers to the Difficulty Level of Concepts.

Discrepancies between the cognitive demands of materials and the cognitive abilities of students present problems for the science teacher. For the teacher to select appropriate materials and/or adapt materials for learner needs, an understanding

of the major types of concepts is essential. The major types of concepts are: (a) classificatory or taxonomic concepts, (b) relational concepts, and (c) operational concepts or intellectual skills (Hurd, 1971). The adjectives concrete-abstract are used to distinguish between concepts which have real world referants and those which do not. The terms lower-order (few) and higher-order (many) are used to describe the levels of organization implied in a classificatory concept. The relative difficulty of various types of concepts is illustrated in a simple linear fashion in Table 4. Teachers should realize, however, that interactions occur among the various types of concepts. For example, classificatory concepts are linked by relational concepts, as well as by the superordinate - subordinate structure, and abstract (formal) operational concepts are a necessary precursor for the use of multiple classification systems (Gagne & White, 1978; Piaget, 1964; Lowell).

Insert Table 4 about here

Sensitize Elementary Teachers to the Levels of Concept Development.

The ability of a teacher to teach and to assess conceptual understanding would be enhanced by an understanding of the stages of concept development. A simple scheme such as the following adaptation of Voelker's (1972) model, could be used:

1. identification of attributes;
2. identification of examples and non-examples;
3. identification of principles relating concepts;
4. identification of meanings or definitions;
5. identification of subordinate and supraordinate concepts;
6. identification of critical attributes.

Teachers could use the model to plan questions and/or to design informal and formal assessments. Although the sequence is not static, and overlap occurs, it would provide a measure of the relative level of concept attainment.

Familiarize Elementary Teachers With Concept Mapping Techniques.

Because of the strong influence of a student's conceptual system on concept attainment elementary teachers need: (a) to understand the importance of concept mapping, (b) to be able to effectively implement group and individual concept mapping activities in the classroom, and (c) to be able to recognize critical features of concept maps. Various techniques for constructing and using concept maps are described in articles by Stewart, Van Kirk, & Rowell (1979), Novak (1980, 1981), and Stewart (1980). Of paramount importance is the teacher's ability to engage the students in a discussion of the reasons for placement of concepts in a particular category and the various ways that the concepts are interrelated. Novak (1981) and Champagne, Klopfer, Desena, and Squires (1981) have developed

complex systems for scoring maps. While most teachers could not utilize the systems per se, the systems do sensitize one to the major variables e.g., correctness, degree of hierarchy, number and complexity of relations expressed, etc.

Train Teachers to Effectively Utilize Concrete Experiences.

Because elementary teachers are reluctant to use laboratory experiences, pre-service and in-service courses frequently stress concrete activities but do not emphasize that movement from subverbal to verbal understanding of a concept is dependent upon application of the principles which promote concept development. Table 4 illustrates how techniques that promote concept development can be effectively integrated with the SCIS Learning Cycle.

Insert Table 5 about here

General principles identified by Clark such as focusing the student's attention on critical and non-critical attributes, presenting examples in an orderly fashion, and moving from obvious to subtle examples can be used by the teacher during the Exploration Phase. During the Concept Invention Stage, teachers can provide "definitions" that communicate the critical attributes and can actively question students to determine the level of concept development. During the Discovery Phase, student ability to generalize, discriminate, and retain the concept

can be improved by providing a large number and range of examples and focusing on the critical attributes (Tennyson and Park). The SCIS Learning Cycle is firmly grounded in learning theory; however, teachers may not perceive the importance or reason(s) for each stage. By emphasizing both the experiential (concrete) stages and the verbal (language) development components, teachers may become more adept at developing concepts.

Conclusion

The purposes of the paper were to summarize the findings of a research study on the influence of selected student variables on the development of ecological concepts and conceptual systems and to discuss implications of the research for the design of elementary curricula and the training of elementary teachers. A paper-pencil test and free-sort categorization task was administered to SCIS students, grades 4-6. Major findings of the study were: (a) grade and ability, not sex, influenced concept attainment and conceptual systems; (b) the sequence of concept development was not influenced by grade, ability, or sex; (c) sixth graders conceptualized life requirements, feeding relationships, food-mineral cycle, and community-environment interactions but not the higher-order classificatory concepts or the oxygen-carbon dioxide cycle; (d) discipline experts, not elementary students, possessed conceptual systems based upon higher-order concepts; and (e) concept attainment was promoted by a conceptual system similar

to the discipline structure. Implications for the elementary educator are: (a) evaluate the effectiveness of elementary programs in developing ecological concepts, (b) sensitize elementary teachers to the difficulty levels of concepts and the sequence of concept development, (c) familiarize elementary teachers with concept mapping techniques, and (d) train teachers to effectively utilize concrete experiences.

References

- Allen, L. R. (1975). Using a single topic film with elementary children. Journal of Research in Science Teaching, 12, 293-295.
- Bishop, S. (1982). Indmtrx: a fortran IV program for converting raw data to a matrix [Computer Program]. Charlottesville, VA: University of Virginia Academic Computing Center.
- Bishop, S. (1982). Sicvalu: a fortran IV program for calculating the sorter intersection coefficient [Computer Program]. Charlottesville, VA: University of Virginia Academic Computing Center.
- Bishop, S. (1982). Sicvalu: a fortran IV program for calculating the sorter intersection coefficient [Computer Program]. Charlottesville, VA: University of Virginia Academic Computer Center.
- Bohl, W. B. (1977). A survey of the cognitive and affective components of selected environmentally related attitudes of tenth and twelfth grader students in six midwestern, four western, and twelve plains and mountain states. Dissertation Abstracts International, 37, 4717-A.
- Boulanger, F. D. (1981). Ability and science learning: a quantitative synthesis. Journal of Research in Science Teaching, 18, 113-121.
- Butts, D. P. (1963). The degree to which children conceptualize from science experiences. Journal of Research in Science

- Teaching, 1, 135-143.
- Champagne, A. B., Klopfer, L. E., Desena, A. T., & Squires, D. A. (1981). Structural representations of students' knowledge before and after science instruction. Journal of Research in Science Teaching, 18, 97-111.
- Clark, C. D. (1971). Teaching concepts in the classroom: a set of teaching prescriptions derived from experimental research. Journal of Educational Psychology Monograph, 62, 253-278.
- Gagne, R. M. & White, R. T. (1978). Memory structures and learning outcomes. Review of Education Research, 48, 187-222.
- Goldman, A. E. & Levine, M. A. (1963). A development study of object sorting. Child Development, 34, 649-666.
- Hambleton, R. K. & Sheehan, D. S. (1977). On the evaluation of higher-order science instructional objectives. Science Education, 61, 307-315.
- Harasyn P. & Precht, D. (1971). A fortran IV program for latent partition analysis [Computer Program]. Alberta : University of Alberta Division of Educational Research.
- Hurd, P. D. (1971). New directions in teaching secondary school science, Chicago: Rand McNally, 1971.
- Karplus, R. A., et al. (1974). Science curriculum improvement study, Berkeley, CA: University of California, Lawrence Hall of Science.

- Lowell, W. E. (1979). A study of hierarchical classification in concrete and abstract thought. Journal of Research in Science Teaching, 16, 255-263.
- Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K. & Bent, D. H. (1975). Statistical package for the social sciences, 2nd ed. New York: McGraw-Hill.
- Novak, J. D. (1980). Learning theory applied to the biology classroom. The American Biology Teacher, 42, 280-285.
- Novak, J. D. (1981). Applying learning psychology and the philosophy of science to biology teaching. The American Biology Teacher, 43, 12-20.
- Otis, A. S., & Lennon, R. T. (1969). Otis-Lennon mental ability test, elementary I. New York: The Psychological Corporation.
- Perkes, A. C. (1973). A survey of environmental knowledge of tenth and twelfth grade students from five great lakes and six far western states. (Doctoral Dissertation). Columbus, OH: The Ohio State University. (ERIC Document Reproduction Services No. ED 080 350)
- Perry, G. F., & Merkle, D. F. (1976). Validity and reliability of the SCIS test for the organisms unit. Journal of Research in Science Teaching, 13, 243-250.
- Piaget, J. (1964). Development and learning. Journal of Research in Science Teaching, 2, 1976-79.
- Preece, P. W. F. (1978). Exploration of semantic space: review

- of research on the organization of scientific concepts in semantic memory. Science Education, 62, 547-562.
- Preece, P. F. W. (1977). Developmental trends in the continued word associations of physics students. Journal of Research in Science Teaching, 14, 235-239.
- Reichard, S., Schneider, M., & Rapaport, D. (1944). The development of concept formation in children. American Journal of Orthopsychiatry, 14, 156-162.
- Richmond, J. M., & Morgan, R. F. (1977). A national study of the environmental knowledge of fifth year pupils in England. (Environmental Education Information Report). Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC Document Reproduction Service No. ED 134 478).
- Stewart, J. Techniques for assessing and representing information in cognitive structure. (1980) Science Education, 64, 223-235.
- Stewart, J., Van Kirk, J. & Rowell, R. (1979). Concept maps: A tool for use in biology teaching. The American Biology Teacher, 41, 171-175.
- Tamppari, R. P. (1970). A model for determining biological concept attainment. Dissertation Abstracts International, 31, 654-A.
- Tennyson, R. D. & Park. O. (1980). The teaching of concepts: a review of instructional design research literature. Review

of Educational Research, 50, 55-70.

- Voelker, A. M. (1973). Research on concept learning: an analysis.
(Occasional paper series - Science Paper II), Columbus,
OH: ERIC Clearinghouse for Sciences, Mathematics, and Environmental
Education. (ERIC Reproduction Service No. ED 091 163)
- Voelker, A. M. (1972, April). Elementary school children's
level of attainment of selected classificatory science concepts.
(Paper presented at the meeting of the National Association
of Research in Science Teaching, Chicago, IL). (ERIC Reproduction
Service No. ED 073 915)
- Winn, W. (1980). The effect of word block diagrams on the
structuring of science concepts as a function of general
ability. Journal of Research in Science Teaching, 17, 201-213.

Table 1

The Influence of Ability, Grade, and Sex on the Development of Ecological Concepts and Conceptual Systems.

Question	Dependent Variable	Statistic(s)	Findings ($p \leq .05$)		
			Grade	Ability	Sex
1. Is conceptual understanding of the ecosystem related to the grade level, ability level, or sex of the student?	Ecosystem Test	3-way ANOVA Scheffe	Yes 6>5>4	Yes HA>A>BA	No
2. Is the sequence of development of conceptual understanding of the ecosystem related to the grade level, ability level, or sex of the student?	Rank Order of Ecosystem Test Items by Difficulty	Spearman Rank Order Correlation	No	No	No
3. Is the similarity of a student's conceptual system and the discipline structure related to the grade level, ability level, or sex of the student?	SIC* Value	3-way ANOVA Scheffe	Yes 6>4	Yes HA>BA	No
4. Is the similarity of a male or female student's conceptual system and the discipline structure a predictor of conceptual understanding of the ecosystem when the influence of grade level and ability level are removed?	Ecosystem Test Score	Multiple Regression	Controlled	Controlled	SIC* value predicts Ecosystem Test Scores of male and female students

Note: SIC is the value calculated using the formula, $N_{ij}/\sqrt{N_i} \sqrt{N_j}$, for the Sorter Intersection Coefficient (Hart and Toews).

Table 2

Descriptive Information on Ecological Concepts Attained by
Sixth Grade Students.

Difficulty Range	Difficulty Level	Question Number	Summary of Content of Test Item
Very Easy (.85-1.00)	.958	3	Example of food eater.
	.948	34	Interpretation of food webs--animals.
	.938	35	Interpretation of food webs--animals.
	.918	36	Effect of removing animal eater's food source.
	.917	21	Life requirements of animals.
	.896	14	Example (drawing) of community.
	.875	5	Life requirements of plants.
	.865	26	When dead things rot minerals are formed.
Moderately Easy (.60-.84)	.833	18	Example of non-living thing plants and animals need.
	.823	27	Minerals are formed from rotting organisms.
	.802	24	A bad odor is evidence of decay.
	.802	33	Interpretation of food webs--plants.
	.792	37	Effect of removing plant eater's food source.
	.771	13	Interaction: decayers/plants, food-minerals.
	.750	46	When dead things rot minerals are formed.
	.729	8	Example of decomposers.
	.719	28	Example of consumers.
	.708	10	Example of environmental factors.
	.677	2	Example (drawing) of ecosystem.
	.677	39	Interaction: producer/consumer, food-minerals.
	.677	4	Interaction: plants/animals, O_2 - CO_2 .
	.667	11	Definition of community.
	.635	43	Definition of environmental factors.
	.615	15	Description (attribute) of community.
	.615	31	Definition of ecosystem.
	.605	30	Interaction: plants/animals, food.
Moderately Hard (.35-.59)	.594	38	Plants obtain energy from the sun.
	.594	44	Interaction: producers/decomposers, O_2 - CO_2 .
	.583	19	Interaction: plants/decomposers, O_2 - CO_2 .
	.563	45	Animals convert food to energy, H_2O , CO_2 .
	.531	17	Interaction: producers/consumers, O_2 - CO_2 .
	.531	22	Definition of consumer.
	.521	9	Description (attribute) of producer.
	.510	16	Using food chain to represent relationships.
	.510	41	Definition of decomposer.
	.490	12	Plants obtain water/minerals from the soil.
	.479	1	Description (attribute) of decomposer.
	.448	40	Description (attribute) of ecosystem.
	.406	42	Example of decayer.
	.396	7	Interaction: producers/decomposers, food-minerals.
	.375	20	Definition of producer.
	.365	23	Example of producer.
Very Hard (.00-.34)	.323	29	Example of a food maker.
	.292	32	Description (attribute) of consumer.
	.271	6	Description (attribute) of environmental factors.
	.188	25	Oxygen is used in decay.

Table 3

Descriptive Information on Conceptual Systems of Fourth, Fifth, and Sixth Grade Students and Discipline Experts

Population	Composition of Groups					
	1	2	3	4	5	6
Discipline Experts	producer bush corn oak	consumer beetle grasshopper prairie dog	decomposer bacteria mold	environmental factors carbon dioxide water	community	
Sixth Grade (SIC = .595)	bush oak	beetle grasshopper prairie dog	bacteria mold	corn water	consumer decomposer producer	carbon dioxide community environmental factors
Fifth Grade (SIC = .564)	bush oak	beetle grasshopper prairie dog	bacteria mold	corn water	carbon dioxide community consumer decomposer environmental factors producer	
Fourth Grade (SIC = .512)	bush oak	beetle grasshopper prairie dog	bacteria mold	corn water	carbon dioxide community consumer decomposer environmental factors producer	

Note: Grade 6 > Grade 4 ($p < .001$).

Table 4
Relative Difficulty Levels of Concepts

LOW DIFFICULTY	HIGH DIFFICULTY LEVEL
CONCRETE CLASSIFICATORY CONCEPTS Real World Objects and Sensory Experiences e.g. plant, cold	ABSTRACT CLASSIFICATORY CONCEPTS No Tangible Referants e.g. atom, molecule.
LOWER-ORDER CLASSIFICATORY CONCEPTS Few Levels of Organization e.g. plant -> community	HIGHER-ORDER CLASSIFICATORY CONCEPTS Multiple Levels of Organization plant -> producer -> community -> ecosystem
CONCRETE RELATIONAL CONCEPTS Interactions of Concrete Objects e.g., predator-prey	ABSTRACT RELATIONAL CONCEPTS Principles, Laws, Theories e.g. Kinetic Molecular Theory
CONCRETE OPERATIONAL CONCEPTS Simple intellectual skills, e.g., conservation, interaction, ordering, additive reasoning, simple classification.	ABSTRACT (FORMAL) OPERATIONAL CONCEPTS Advanced intellectual skills, e.g. correlation, probability, ratio-and- proportion, hierarchical classification

Note: Terms and definitions are based upon Hurd (1971), Lowell (1979), and Piaget (1964).

Table 5

Application of Concept Development Principles to the SCIS Learning Cycle

EXPLORATION (Concrete Experiences)	INVENTION (Concept Development)	DISCOVERY (Concept Application)
. Provide an orderly display of examples. . Move from obvious to subtle examples. . Leave examples in full view. . Ask questions that draw students' attention to critical and non-critical attributes. . Ask questions that encourage students to state the concept in their "own words."	. Keep examples in full view. . Provide a concept "definition" that identifies and communicates the critical attributes. . Be aware of levels of concept development and utilize in developing the concept: . examples and non-examples . principles . meanings and definitions . subordinate-superordinate relationship . critical attributes.	. Move from obvious to subtle examples. . Increase retention by providing a large number of examples. . Increase ability to generalize by providing a wide variety of examples. . Increase ability to discriminate by focusing on critical vs. non-critical attributes.

Note: Concept development principles are derived from Clark (1971), Tennyson & Park (1980), Voelker (1972).